PO-0793

Assessment of kV cone-beam CT dose, for children undergoing image-guided radiotherapy.

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Purpose/Objective: Treatment plans for children undergoing radiation therapy become increasingly complex due to increased use of IMRT/arc therapy.This puts higher demands on patient positioning accuracy. Daily kV cone beam computed tomography (kVCBCT) is an excellent tool for this purpose, but it does also add an additional dose to normal tissue close to the treatment area. The purpose for this study was to determinate a quantitative method for the estimation of kVCBCT doses in pediatric patients undergoing image-guided radiotherapy.
Materials and Methods: The dosimetric concept generally used in CT is basedon measurements of the computed tomography dose index (CTDI). The CTDI is measured with ionization chamber in a standard dosimetry phantom, and the effective dose and organ dose is calculated using a standard tool like the Excel-program CT Expo.There are several challenges in extending this method to CBCT, including definition of CTDI for a cone beam, different beam quality due to filtering, and the fact that CBCT can be limited to a 200° scan angle for head and neck modes. We have therefore measured dose in selected organs in anthropomorphic children phantoms corresponding to the age 1, 5 and 10 years with the romluminescence detectors (TLD). These measurements were compared to doses calculated by astandard CTDI approach/ CT Expo, and the differences assessed.
Results: We found significant differences in the doses given bythe CTDI approach and direct measurements with TLDs. Especially this is true for the dose to lens, where the selected scan range for a 200° scan is the main contributing factor.
Conclusions: The well-known methods from CT such as CTDI can not be directly adapted for kVCBCT images. In the absence of standardized absorbed dose metric comparable with the CTDI used in conventional CT, estimation of an effective dose should be calculated from point dose measurements with TLD detectors in anthropomorphic phantoms. In a clinical setting CBCT at an accelerator typically have only a few predefined settings of kV and mA depending on anatomical region. It is therefore advisable to keep a table over measured organ doses in anthropomorphic phantoms for standard clinical conditions as a reference.

PO-0794

Evaluating the usefulness of EPID for daily output verification by comparison to ionization chamber measurements

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Purpose/Objective: To investigate the long term stability of the amorphous silicon electronic portal imaging device (aSi EPID) for monitoring medical linear accelerator output, by a) acquiring output data on a daily basis using the EPID, b) correlating EPID data to weekly measurements using an ionization chamber in a Perplex phantom and c) correlating as well as calibrating EPID response to absolute measurements with an ionization chamber in water.
Materials and Methods: A test patient, including two open fields (25x25 cm^2, 6 and 15 MV) intended for output measurements with the EPID, was defined. During a period of > 8 months, daily measurements were performed on 9 different medical linear accelerators (8 x Varian Clinac 2300iX and 1 x Varian TrueBeam), equipped with aSi EPIDs (Varian aS1000). Data from the EPID measurements was extracted, using a in-house software developed in MATLAB©, and compared to weekly output measurements with an ionization chamber in a Perplex phantom as well as to quarterly (or on indication) measurements with an ionization chamber in water. Calibration of the EPIDs were performed in conjunction with the ionization chamber measurements in water, also at which point the LINAC output was adjusted to within ±0.3% of the reference data based on the measurements in water.
Results: The ability of the EPID to detect output variation was confirmed by the correlation between the EPID measurements and the ionization chamber measurements in the Perplex phantom as well as in water (Figure 1), for both the Varian Clinac 2300iX as well as for the TrueBeam. However, a variation in performance between some EPIDs is present, possibly in some extent as a result of the differences in the wear and tear of the EPIDs. It is also clear that a daily variation of the EPID data exists and needs to be considered when selecting tolerance levels. Some of the EPIDs detected a greater increase in output over time in comparison to the increase in output detected by the ionization chamber measurements. However, regular calibration of the EPIDs in conjunction with the measurements in water proved to be a solution for this exception.

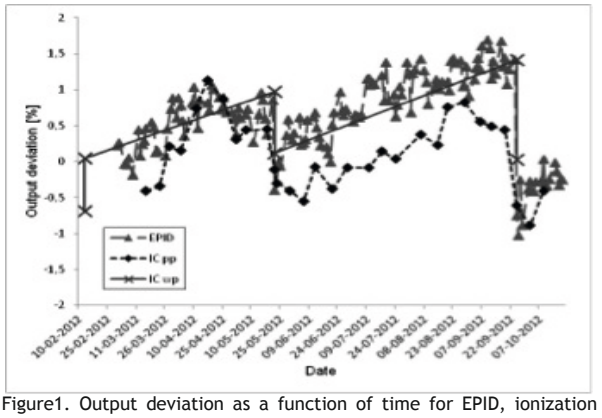

Figure1. Output deviation as a function of time for EPID, ionization chambermeasurements in a Perplex phantom (IC pp) and ionization chamber measurementsin a water phantom (IC wp).

Conclusions: The Varian aSi EPID has been proven to be suitable for fast relative measurements of the LINAC output on a daily basis. However, regular (at least quarterly) calibrations of the EPIDs are essential for a clinic to be able to rely on the EPID as a quality assurance tool for daily verification of the LINAC output.The user independence and the fact that it is a two-dimensional detector mounted directly on the LINAC is some of the important advantages, giving also the possibility to readily verify beam quality, beam profile parameters (e.g. symmetry, flatness and field size) and MLC performance.

POSTER: PHYSICS TRACK: DOSE CALCULATION

PO-0795

Validation and one year experience with an independent redundant calculation software for VMAT fields

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Purpose/Objective: It is accepted that the QA process previous to any treatment must include a redundant independent dose calculation. For conventional radiotherapy these calculations could even be performed manually using dosimetric data. On the other hand, for intensity modulated fields more complex software is required. Diamond ('K&S Associates') is a software with capabilities to calculate VMAT (Volumetric Modulated Arc Therapy) fields. Validation and one year experience for VMAT fields are presented in this work.
Materials and Methods: For VMAT validation, a set of 59 clinically accepted plans was selected including different locations. The treatment planning system (TPS) used was Eclipse v10.0. First, the plans were recalculated on a cylindrical phantom. The recalculated plans were then exported to Diamond, where dose calculation was carried out at the isocenter. In Diamond, non-water equivalent relative electronic density of phantom was accounted for by setting an effective depth determined by the TPS. Results were analyzed obtaining average deviations and standard deviation values from the comparisons Diamond versus measurements and versus TPS. Experimental measurements were performed by using a pin-point chamber. In one year 476 VMAT plans were produced. These plans were grouped by location (abdomen, prostate, pelvis, torax, lung, brain, H&N, radiosurgery and SBRT), recalculated in the TPS without heterogeneity and then, exported to Diamond including body contour. A comparison between Diamond an Eclipse at isocenter was made.
Results:
Validation: An average dose deviation of -0.2 ± 1.7%(1SD) was obtained between Diamond and measurements. Only 2 of 59 values had a deviation above ±3.5% (+5.1 and -4.6%), a linear fit produced a correlation coefficient of 0.9945. Between Diamond and TPS the average deviation found was 0.0 ± 1.6%, correlation coefficient was 0.9951.
One year results: An average deviation of -0.3 ± 1.9% was obtained for the total of plans a linear fit produced a correlation coefficient of 0.9991.Deviations greater than 4% was obtained in 7 plans and maximum deviation of +5.0% was obtained in one plan.
It should be noted that a calculation point different from the isocenter was chosen in one case in the validation process to avoid

hight dose gradient regions. This same was made in 7 clinical plans. Also, 2 plans in validation and 8 plans in clinical practice were recalculated in an alternative phantom due to geometric uncertainties.
Conclusions: The agreement between measurements and Diamond may be interpreted as an absence of systematic errors. In the same way the comparison between Eclipse and Diamond produced very similar results. One year experience shows results very close to those obtained in validation. This agreement led us to consider Diamond a valuable tool for QA in VMAT plans.

PO-0796
Independent dose calculation with X-ray Voxel Monte Carlo Algorithm in Volumetric Modulated Arc Therapy
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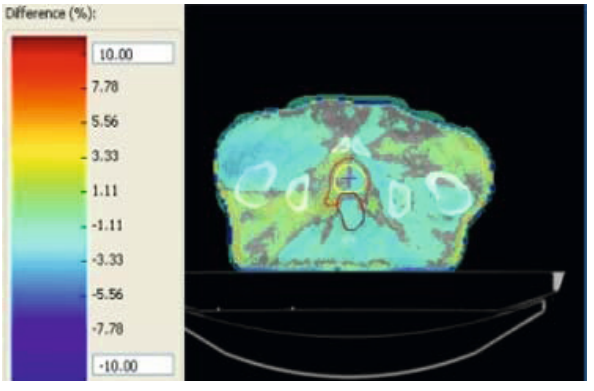
Purpose/Objective: The MONACO treatment planning system (TPS) (Elekta), which employs an X-ray Voxel Monte Carlo (XVMC) algorithm is currently used in radiation therapy. The XVMC calculation is reliable for determining absorbed dose of X-ray in the heterogeneous region. Therefore, the MONACO TPS could be useful for an independent dose calculation in a high precision treatment. So, we developed a conversion program of a beam format in Pinnacle^3 TPS to that in MONACO TPS. In this study, we present the dose comparison between them for prostate, lung, head and neck, and esophagus cancer patients treated by Volumetric Modulated Arc Therapy (VMAT).
Materials and Methods: Eight patients (prostate; 5, lung; 1, head and neck; 1, esophagus; 1) treated by single-arc VMAT were selected for this study. The treatment plan was created by SmartArc (Pinnacle^3, Philips) with the superposition/convolution algorithm. The calculation voxel space was 2 mm. Then, the beams from SmartArc were exported into the MONACO TPS, where the dose distribution was recalculated with 3 mm of the calculation voxel space and 3% of the variance. The comparison was performed by analysing the dose volume histogram (DVH) and the dose difference.
Results: The differences in PTV D50 (covering 50% of the planning target volume) were about 0.6%, 1.4%, 1.2%, and 1.3% for prostate, lung, head and neck, and esophagus cancer cases, respectively. Although the dose difference tended to be relatively large for the organs at risk, the serious discrepancy was not observed. Figure shows one of the examples of the dose difference for a prostate cancer patient.



Conclusions: It was feasible to use a commercially available TPS based on a Monte Carlo code as an independent dose calculation for VMAT. In this study, the dose comparison was performed in the various parts, so that no remarkable difference between the superposition/convolution calculation and XVMC calculation was found.

PO-0797
Stereobody for lung cancer: X-ray Voxel Monte Carlo vs Pencil Beam based dose calculation
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Purpose/Objective: The purpose of this study is to evaluate the differences between dose distributions calculated with Pencil Beam (PB) and X-ray Voxel Monte Carlo (XVMC) algorithm. Calculations performed with the PB algorithm is reasonably accurate for tumors located in homogeneous regions but PB tends to overestimate the dose distribution where large inhomogeneities exist. Moreover, for intensity modulated radiation therapy (IMRT) dose calculation can be more complex due to the combined effect of many small fields and the presence of steep fluence gradients.
Materials and Methods: Treatment plans were developed for 45 lung cancer patients with iPlan, Brainlab. For each patient an IMRT or HybridArc plan calculated with PB algorithm was developed to give 40 Gy at 8 Gy/ fraction with five no coplanar 6 MV beams or 3-4 dynamic conformal arcs with 3-5 IMRT beams distributed per arc (for HybridArc plans). Each optimized plan was recalculated with the XVMC algorithm with the same monitor units (MU). Secondly XVMC plans were renormalized to give the prescribed dose to the tumour and differences between MU to be delivered were evaluated. For four patients, evaluations have been performed also in the case of CT scans acquired under deep- breath condition. Differences in dose distributions were evaluated in terms of dose volume histograms (DVHs). To estimate the impact of the observed differences on treatment outcome, tumour control probability (TCP) and normal tissue complication probability (NTCP) were calculated. Thirdly a typical IMRT treatment plan was performed on CT data of an anthropomorphic phantom and calculated doses on significant planes were compared to measurements performed with GAFCHROMIC™ EBT3.
Results: Differences between mean tumour dose calculated with PB and XVMC were about 10±4 %, even larger in deep-breathing conditions, while differences between doses to significant volumes for organs at risk (OARs) were generally lower. After normalization, MUs for XVCM were always higher than for PB though not significantly ($p = 0.0531$). TCP ranged from (99.9 ± 0.1) % to (87.1 ± 9.7) % for PB calculated plans respect to XVMC while NTCP on OARs did not vary significantly. In the deep-breathing condition TCP ranged from (99.9 ± 0.3) % to (66.9 ± 17.2) % for PB and XVMC, respectively. The dosimetric evaluation confirmed the better accuracy in calculation of XVMC, the agreement in terms of absolute gamma function (gamma<1, 3 %, 3mm) was about 94 % for XVMC and lowered down to 67 % for PB.
Conclusions: Results showed that PB calculation leads to overestimate the dose with respect to the XVMC for the points inside the tumour, for each case the major discrepancies were observed along the boundary between tissue and air. The increase in MU due to the renormalization of the plans to have comparable mean doses to the tumour was not significant and the calculated NTCP values for OARs were far below the allowed tolerable values.

PO-0798
Scattering contributions in out-of-field dosimetry using Monte Carlo calculation for breast conserving therapy
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Purpose/Objective: Out-of-field dose to multiple organs has been evaluated for secondary cancer risk assessment using Monte Carlo calculation for breast preserving radiotherapy. Dose contributions from internal body scattering and linac head scattering have been separately calculated and compared.
Materials and Methods: Monte Carlo codes, EGSnrc and DOSXYZnrc,were employed to evaluate out-of-field dose to various organs of breast cancer patients who received breast conserving radiotherapy. The out-of-field dose results from linac head scattering as well as internal body scattering ofdirect x-ray beams. These two scattering contributions were separately calculated by the Monte Carlo codes with a photon energy of 6 MV and a dosegrid size of 4 x 4 x 6 mm^3. Doses on the patient body surface and in various organs were calculated, whereas patient doses were also measured using glass rod dosimeters, GD-301 (Chiyoda Technol, Japan), in various body surface locations. To reduce statistical uncertainty, the number of photons was increased to 1 x 10^{10}. To further verify the accuracy of the Monte Carlo calculation for the patient, surface and internal doses of RAND phantom were also calculated and compared to measured results using the glass rod dosimeter.